Urea flux in beef steers: effects of forage species and nitrogen fertilization

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Urea flux in beef steers: Effects of forage species and nitrogen fertilization[1]

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ABSTRACT: The effects of two forage species and N levels on urea kinetics and whole-body N metabolism were evaluated in eight Angus steers (initial BW 217 ± 15 kg). In a replicated, 4 × 4 Latin square design, steers were fed gamagrass (*Tripsacum dactyloides* L.) or switchgrass (*Panicum virgatum* L.), each of which had 56.2 (LO) or 168.5 (HI) kg of N fertilization per hectare. Diets provided adequate energy for 0.5 kg ADG. Nitrogen balance and urea kinetics were measured from d 22 to 27 of each period. Urine samples collected during intravenous infusion of bis ^{15}N urea were used to calculate production and recycling of urea N from relative abundance of urea isotopomers. Jugular blood serum was analyzed for serum urea N (SUN). Gamagrass differed from switchgrass ($P < 0.05$) in daily DMI (4,273 vs 4,185 g), N intake (72 vs 67 g), DM digestibility (61.0 vs 63.6%), fecal N (30.6 vs 28.3 g/d), urine urea N (10.5 vs 8.0 g/d), and percentage of urinary N present as urea N (53.5 vs 40.0%). After adjustment for differences in N intake, fecal N still tended to be greater ($P < 0.09$) for gamagrass than for switchgrass. The LO differed from the HI ($P < 0.01$) in daily N intake (63 vs 76 g), DM digestibility (61.3 vs 63.3%), urine N (13.6 vs 25.9 g/d), and N retained as a percentage of N digested (57.3 vs 43.5%). Compared to switchgrass, gamagrass had greater SUN, N digestibility, and N digested as N level increased (forage × N level interactions, $P < 0.05$). As N level increased, N retention increased from 19.5 to 23.5 g/d in gamagrass and decreased from 20.5 to 18.1 g/d in switchgrass (interaction, $P < 0.07$). The HI group was greater than the LO intake group ($P < 0.03$) in endogenous production of urea N (44.4 vs 34.0 g/d), gut entry rate of urea N (31.6 vs 28.2 g/d), and the amount of urea N that re-entered the ornithine cycle (9.4 vs 7.9 g/d). However, the percentage of urea N entering the gastrointestinal tract that was recycled was constant among treatments (29.1%), indicating that almost 70% of the urea N that entered the gastrointestinal tract was potentially available for anabolic purposes of the steers as a component of microbial products that were absorbed or excreted in the feces. In summary, N levels affected N metabolism of steers more when they were fed gamagrass than when they were fed switchgrass. Although the absolute amounts of N moving through the system changed with variations in intake, the proportions remained similar, with a greater efficiency of N use at low N intakes.

Key Words: Beef Steers, Gamagrass, Switchgrass, Urea Kinetics

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Introduction

As concerns for environmental damage instigated by agricultural processes increase, there is a greater need to develop more ecologically acceptable methods of producing agricultural products. Therefore, beef producers want to minimize N excretion and maximize N retained as salable beef or other products of beef production.

Urea, the major end product of ammonia and amino acid metabolism in beef cattle, is excreted in urine or recycled to the gastrointestinal tract (**GIT**) by diffusion across the gut wall or in saliva. The quantity of urea N that enters the GIT is equivalent to 30 to 77% of dietary N (Sarraseca et al., 1998; Huntington, 1989). Urea that is recycled to the GIT is hydrolyzed to yield ammonia, which is used as a source of N for microbial protein, reabsorbed into blood circulation, or lost as fecal N. Many of the cellulolytic bacteria prefer NH_3 as the source for N (Russell et al., 1992), so recycled urea provides a mechanism by which N may be salvaged into bacterial matter that may be digested by the animal to provide amino acids for production purposes. The amount of recycled urea N that is retained for possible anabolic purposes of the ruminant can be influenced by dietary factors such as intake (Sarraseca et al., 1998), level of dietary concentrate (Huntington et al., 1996), and level of dietary N (Bunting et al., 1987). The purpose of this study was to determine the effects of dif-

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Table 1. DM composition of the supplement

Ingredient	%
Cracked corn	90.81
Mono-dicalcium phosphate	3.49
$CaCO_3$	1.85
NaCl	1.96
Vitamin premix[a]	0.73
Cane molasses	0.51
Rice meal by-product	0.46
Trace mineral premix[b]	0.19

[a]Contained per kilogram of supplement DM: 5,000 IU of vitamin A, 625 IU of vitamin D, and 114 IU of vitamin E.
[b]Cu (502 mg/kg) as $CuSO_4$; Mg (50,240 mg/kg) as MgO; Zn (1,500 mg/kg) as $ZnSO_4$; Co (5 mg/kg) as $CoCO_3$; Se (5 mg/kg) as Na_2SeO_4; and Cr (1,080 mg/kg) as Cr-picolinate.

fering amounts of N and digestible carbohydrate in two warm-season grasses on N metabolism, and urea kinetics in particular, in growing beef steers.

Materials and Methods

Animals and Experimental Procedures

The experimental design was a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of forage species and N level in the forages. Gamagrass (*Tripsacum dactyloides* L.) and switchgrass (*Panicum virgatum* L.) were fertilized with either 56.2 (**LO**) or 168.5 (**HI**) kg of N per hectare and harvested at vegetative stage of maturity. One field of each forage was grown and harvested as described by Burns et al. (1997). Periods lasted 27 d, with 21 d of adaptation and 6 d of sample collection.

Eight Angus steers (initial weight 217 ± 15 kg; final weight 252 ± 9 kg) were used in this experiment. Care, handling, and sampling of these steers were approved by the North Carolina State University Animal Care and Use Committee. Steers were purchased at a North Carolina feeder calf sale and quarantined for 28 d; they were trained to be led by halter and accustomed to close human interaction during quarantine. Steers were then blocked by BW into two groups of four steers each and housed in indoor, individual tie stalls (115 × 178 cm). Steers had ad libitum access to water. The diurnal pattern consisted of 12 h of light and 12 h of dark. The steers were allowed to exercise in an outdoor pen two to three times a week for 3 to 4 h between collection periods. Steers were adapted to the facilities, infusion equipment, and urine collection apparatus during a 21-d adaptation period before the experiment began. During this pre-experimental period the steers received the experimental hays in a randomized fashion such that each steer received each of the hays in a given 4-d period. Steers also were fed a supplement (Table 1) that provided all vitamins and minerals necessary for desired growth (0.5 kg/d; NRC, 1996).

Diets were formulated to provide adequate energy for 0.5 kg ADG, and metabolizable protein was slightly below requirements for maintenance (LO) or adequate for 0.5 kg ADG (HI) by NRC (1996) recommendations for a 250-kg growing steer. Those criteria were met by feeding 3.78 kg DM of hay and 0.44 kg DM of supplement (Table 1) daily. The hay was offered in two equal portions at 1000 and 1630 and the supplement was offered with the 1000 feeding. Prior to sample collections, stalls were thoroughly cleaned. Wooden panels were attached to one side of the pens to minimize cross-contamination of feces between steers. These panels allowed visual contact among steers. Clean, plastic tarps were positioned behind each steer to facilitate quantitative collection of feces. Steers were then fitted with two temporary catheters in the same exterior jugular vein with tips 10 cm apart in the vena cava 48 h prior to the beginning of the digestion trial. The catheter whose tip was closest to the heart was used for infusions, and the other catheter was used for blood sampling. Patency of catheters was maintained with Na-heparin (100 units/mL) in 0.9% sterile saline.

Total collections of urine, feces, and orts were conducted for 6 d following adaptation to the respective diet. Feed was sampled daily during the 6 d of sample collection. Urine was aspirated into polypropylene jugs from a urine collection harness. The urine harness consisted of a urine receptacle (Belko, Kingsville, MD) fitted with cotton belting and elastic with foam rubber pads to allow for movement and comfort of the steers. Urine jugs contained 200 mL of 6 *N* HCl daily. Feces and urine were collected daily and weighed, and an aliquot (5% of daily output) was retained. Feces were scraped back and placed in a plastic storage receptacle throughout each day to minimize problems with steer movements that might have affected the total collections. After the final day of collection, steers were removed from the pens and the pens were thoroughly scraped. Scrapings were included in the final day's output of feces. Urine pH was measured with pH-sensitive paper prior to collection of aliquots to ensure pH < 4. Urine aliquots were pooled within steer and kept frozen at < –4°C. Fecal aliquots were dried with forced air at 60°C for 48 h and then pooled within steer.

Following the first 24 h of the balance trial, samples were collected to establish baseline enrichments of ^{15}N. Urea kinetics subsequently were measured during d 2 through 4 of the balance trial. Steers were infused with sterile 0.9% saline containing bis^{15}N-urea (Cambridge Isotope Laboratories, Andover, MA; Lot T1-41568). Bis^{15}N-urea was infused to allow subsequent determination of urea-N isotopomers ($^{14,14}N$-, $^{14,15}N$-, and $^{15,15}N$-urea). Infusion rate was maintained at 85 mL/h, which delivered 0.137 mmol of urea N/h using a peristaltic pump (Model 1000, Medical Technology Products, Huntington Station, NY). Urine was sampled at 2-h intervals from 48 to 56 h of infusion for determination of ^{15}N enrichments, and blood for measurement of serum urea N (**SUN**) was collected at the same time. In square 1, 71 of a possible 80 and in square 2, 76 of a possible 80 urine samples were collected between 48 to 56 h of

infusion; missing samples were due to lack of urination during the 2-h interval. There were at least three urine samples (in 2 of 16 periods) for each steer and period. The average enrichments of the individual urine samples (corrected for baseline enrichments) within steer and period were used in subsequent ANOVA. The enrichments at this time seemed to be at a plateau. Volumes of samples taken for ^{15}N analysis were accounted for in calculation of total urine excretion.

Chemical Analysis

All feed, orts, and feces samples were ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass through a 1-mm screen and stored at room temperature in sealed containers until they were analyzed. Urine samples were stored in plastic bottles and frozen at < –4°C until they were analyzed. Duplicate samples of feed, orts, and feces were analyzed for DM, ash, and Kjeldahl N using AOAC (1984, 1999) procedures. Neutral detergent fiber, ADF, and 72% sulfuric acid residue of forage samples were sequentially determined using an Ankom 200 fiber extractor (Ankom Technologies, Fairport, NY) according to the method of Van Soest et al. (1991). In vitro true dry matter digestibility (**IVTDMD**) was determined by the disappearance of 0.25-g samples in Ankom fiber bags (Ankom Technologies, Fairport, NY) in vitro for 48 h. Samples were batch-fermented with 1,600 mL of McDougal's buffer (Tilley and Terry, 1963) and 400 mL of strained ruminal fluid using the Ankom II Daisy fermentor (Ankom Technologies). In vitro fermentations were terminated with NDF extraction (Van Soest et al., 1991) in an Ankom 200 fiber analyzer to remove the residual microbial fraction. Urea N concentrations of serum, urine, and ^{15}N-urea infusate were analyzed using the diacetyl monoxime method of Marsh et al. (1957). The N fractions of the forages were described by their solubility in acid or by the fiber fraction with which they are associated (Licitra et al., 1996). Non-protein nitrogen, or the A protein fraction, was determined using a trichloroacetic acid precipitation. The subsequent B_1, B_2, B_3, and C fractions were determined using standard NDF and ADF procedures described above, followed by Kjeldahl N determination. Protein fractions were determined on composite samples of forages and analyzed in triplicate.

For analysis of ^{15}N enrichment of urea, urea was isolated by passage of an aliquot of urine containing 1.5 mg of urea N through 2 mL of a cation exchange resin column (AG-50, 100–200 mesh, ×8, H+ form; Biorad, Richmond, CA). New columns were prepared for each sample by replacing the resin. The new resins were rinsed with 10 mL of 1 *N* NaOH, rinsed twice with 10 mL of N-free water, rinsed twice with 10 mL of 1 *N* HCl, and finally rinsed twice with 10 mL of N-free water. After the urine sample was applied to the column, the column was washed with 7 mL of N-free water, which was discarded, and then urea was eluted by 20 mL of N-free water into glass beakers. Analysis of the eluent with the previously described urea analysis system indicated that approximately 40% of the urinary urea N applied to the column was recovered by this method. Samples were air-dried at 60°C and then were quantitatively transferred to 12- × 75-mm borosilicate glass tubes with three, 1-mL rinses. The samples were then freeze-dried and analyzed via the freeze-layer method of Volk and Jackson (1979) using an isotope ratio cycloidal mass spectrometer (Model 21-620, Consolidated Electrodynamics, Pasadena, CA), where the N_2 gas generated was analyzed in triplicate for abundance of ^{15}N. The NaOBr treatment of urea (Volk and Jackson, 1979) leads to a Hoffman degradation, which, at infinite dilution, yields N_2 gas with both atoms of N arising from the same molecule of urea in monomolecular conditions. Thus, $^{14}N^{14}N$, $^{14}N^{15}N$, and $^{15}N^{15}N$-urea molecules should yield ions with mass/charge (**m/z**) values of 28, 29, and 30, respectively. However, completely monomolecular conditions are not obtained. Therefore, at each time that samples were analyzed, standards (0.6 mg urea N) prepared from the $^{15}N^{15}N$-urea (99.7 atoms % ^{15}N) and natural abundance urea (0.364 atoms % ^{15}N) were used to determine the average proportion of non-monomolecular reactions to correct the m/z 29 and m/z 30 atoms percent excess for non-monomolecular reactions. The enrichments of urea as m/z 29 and m/z 30 were then applied to the model of Sarraseca et al. (1998) to calculate urea-N entry rate (**UER**), the rate at which urea enters the GIT (**GER**, the difference between UER and urea excretion in the urine), and the rate at which NH_3 N from hydrolysis of urea is returned to the ornithine cycle (**ROC**). Urea-N entry rate is an estimate of the de novo production of urea N by the steer, and by calculating the GER we were able to estimate the rate of urea entry into the GIT. The unique nature of this study lies in the estimation of ROC, in that it allows us to demonstrate possible manipulations of N movements into the GIT and demonstrate just how efficiently the N from endogenous urea was utilized.

Statistical Analysis

The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used for statistical analysis of data. The model for balance trial data and urea kinetic data included the following independent variables: square, steer(square), period(square), forage species, N level, and the forage × N level interaction. When treatment effects were significant ($P < 0.05$), a difference was determined and a tendency for treatment to elicit a response was noted when $P < 0.15$.

Results

There were distinct differences in chemical composition between forage species and N levels (Table 2). Switchgrass decreased in hemicellulose with increased N level, but gamagrass had a very small increase in hemicellulose with increased N level. This was accom-

Table 2. Chemical composition, in vitro true dry matter digestibility (IVTDMD), and N fractions of gamagrass and switchgrass hay with low or high N content

	Gamagrass		Switchgrass	
	Low	High	Low	High
% of DM[a]				
Hemicellulose	34.2	34.4	35.0	33.8
Cellulose	31.9	33.3	34.2	32.2
Lignin	4.1	4.5	3.9	3.8
IVTDMD	67.6	65.7	66.2	69.2
CP	9.4	12.1	8.8	11.1
N Fractions[bcd]				
% of CP				
A	20.6	27.0	21.3	24.3
B_1	3.0	3.6	6.0	7.6
B_2	24.6	25.4	27.6	28.7
B_3	47.0	40.1	39.2	35.2
C	4.9	4.0	5.9	4.1
N Fractions[cdef]				
Intake, g/d				
A	12.4	20.5	12.4	16.5
B_1	2.2	3.2	3.8	6.0
B_2	18.4	23.1	19.7	23.2
B_3	28.0	30.7	22.8	24.1

[a]Arithmetic means from duplicate analysis of samples from each diet.
[b]Using the method of Licitra et al. (1996).
[c]Arithmetic means of triplicate analysis of a composite sample.
[d]N fractions from Level 2 NRC (NRC, 1996).
[e]Calculated as (N intake from hay g/d) × N fraction + (N intake from supplement g/d) × N fraction.
[f]N fractions for supplement using cracked corn values (NRC, 1996).

panied by a decrease in cellulose in switchgrass with higher N level, whereas cellulose increased in gamagrass with higher N level. Lignin increased with N level in gamagrass, but it remained nearly the same in switchgrass.

Similar to the changes in cellulose, IVTDMD decreased with increased N level in gamagrass, but it increased with N level in switchgrass. Crude protein was higher in gamagrass than in switchgrass and CP increased with increased N level. The most substantive change was the increase in the readily soluble portion (A) of CP. Gamagrass had less true soluble protein (B_1) than switchgrass, and this was primarily compensated with an increase in the amount of slowly digested (B_3) proportion of CP.

Interactions between forage species and N level affected N digestion and metabolism by the steers (Table 3). There was a greater increase in N digested as N level increased by steers fed gamagrass than by those fed switchgrass (interaction, $P < 0.03$). There was a greater increase in N digestibility as N level increased by steers when fed gamagrass than when fed switchgrass (interaction, $P < 0.04$). Retained N tended to increase with increased N level in steers fed gamagrass, whereas the percentage decreased with increased N level in steers fed switchgrass (interaction, $P < 0.07$). There was a greater (interaction, $P < 0.02$) increase in SUN as N level increased by steers fed gamagrass than by steers fed switchgrass. There was a tendency (interaction, $P < 0.09$) for N intake to increase more between the LO and HI levels of gamagrass than between the LO and HI levels of switchgrass.

Compared with switchgrass, when steers were fed gamagrass DMI increased 90 g/d ($P < 0.04$) and N intake increased 5 g/d ($P < 0.01$). Fecal DM increased 151 g/d ($P < 0.01$), fecal N increased 2.3 g/d ($P < 0.01$), urine urea N increased 2.5 g/d ($P < 0.03$), and urea as a percentage of total urinary N increased 14.1 percentage units ($P < 0.03$). Dry matter digestibility decreased ($P < 0.01$) and SUN increased 0.9 m*M* ($P < 0.01$) as a main effect of forage when steers were fed gamagrass. When steers were fed gamagrass, the percentage of GER decreased 4.8 percentage units ($P < 0.05$).

Compared with LO, when steers were fed HI N intake increased 15 g/d ($P < 0.01$), fecal DM decreased 75 g/d ($P < 0.01$), urine N increased 12 g/d ($P < 0.01$), and urinary urea increased 7 g/d ($P < 0.01$, Table 3). Dry matter digestibility increased 2 percentage units ($P < 0.01$), N digested increased 12.9 g/d ($P < 0.01$), N digestibility increased 7 percentage units ($P < 0.01$), and the proportion of N digested that was retained decreased 14 percentage units ($P < 0.01$) when steers consumed HI. Serum urea N increased 2.3 m*M* ($P < 0.01$, Table 3), UER increased 10.35 g/d ($P < 0.01$), GER increased 3.42 g/d ($P < 0.03$), and ROC increased 1.47 g/d ($P < 0.03$) when steers consumed HI. The data also indicate that GER as a percentage of UER decreased 11.47 percentage units ($P < 0.01$), and ROC as a percentage of UER tended to increase 2.17 percentage units ($P < 0.09$) when steers were fed HI.

Discussion

N Digestibility and Whole Body N Metabolism

This study was conducted with the hypothesis that there would be significant interactions between different grass species with different levels of N in the plant material. This was based on the premise that differences in the available carbohydrate available for digestion could be manipulated through selection of different forage species to improve urea N capture in the rumen. Forage × N level interactions in forage composition (Table 2) were not evident for in vivo DM digestibility (Table 3). Further, IVTDMD predicted no difference between forages, and the forage × N level interaction was largely due to decreased IVTDMD as N level increased for gamagrass. Increased N intake for gamagrass compared to switchgrass was due to the increased N concentration in gamagrass and the slightly greater DM intake. The increased N intake associated with switchgrass was also associated with an increase in fecal N (Table 3). A subsequent ANOVA was conducted, comparing forage species with N intake as a covariate. In that analysis there were no differences between forages ($P > 0.15$), except for a trend for greater ($P < 0.09$) fecal N for gamagrass. The differences in N fractions between forages (Table 2) or the increased N supply was not sufficient to improve in vivo DM digestibility of gamagrass vs switchgrass. We conclude that N availability did not limit ruminal fiber digestion of switchgrass, and that increased in vivo DM digestibility for switchgrass vs gamagrass was due to less lignin in switchgrass.

By design, the N intake was greater for steers receiving HI than for those receiving LO. However, gamagrass had a higher concentration of N than switchgrass, which resulted in a trend for greater N intake between the HI and LO treatments of gamagrass than between the HI and LO treatments of switchgrass (Table 3). The subsequent decrease in fecal DM and increase in apparent DM digestibility with the increased N level support increased fiber digestibility with increased dietary CP, as shown by Willms et al. (1991). Griswold et al. (1996) demonstrated that an increase in the amount of N present as non-urea N increased the extent of structural carbohydrate digestion in a continuous culture system. Thus, due to the moderate increases in the amount of N in the B_1 and B_2 fractions of the HI vs LO forages (Table 2), HI forages should have higher degradability of fiber. The increases in the concentrations of these soluble and readily available, insoluble forms of N are likely the cause of the increased digestion of the forages, rather than the increased levels of NPN in the forages (Rihani et al., 1993).

The greater increment in N digested and N digestibility in response to N level for gamagrass vs switchgrass (Table 3) is associated with greater increments in intake of the A and B_2 fractions of N (Table 2) and higher SUN (Table 3). In agreement with other studies (Bunting et al., 1987; Huntington 1989; Sarraseca et al., 1998) both urinary N excretion and urinary urea excretion increased with the increased N intake (Table 3). The tendency for urea as a percentage of total urinary N to decrease with increasing levels of N in steers fed gamagrass but to increase in steers fed switchgrass is consistent with the presence of antinutritional factors in switchgrass that inhibit N retention. One possible factor is phenolic acid monomers, which can constitute 1 to 2.5% of NDF in switchgrass hay (Jung and Vogel, 1992). These phenolic acid monomers are detoxified by conjugation with glycine in the liver (Cremin et al., 1995), which would result in an increase in hippuric acid production. Hippuric acid would then be released from the splanchnic system into circulation, excreted in the urine, thereby reducing the available N present for anabolic processes of the steers. This concept is supported by the overall decrease in urine N present as urea in steers fed switchgrass.

Table 3. Intake, digestion, retention, and serum urea N (SUN) in steers fed gamagrass or switchgrass hay with low or high N content

	Gamagrass		Switchgrass			*P*-value		
Item	Low	High	Low	High	SE	Grass (G)	N level	G × N
DMI, kg/d	4,278	4,267	4,140	4,227	0.040	0.041	0.362	0.241
N intake, g/d	64.0	80.5	62.2	72.3	1.73	0.011	0.001	0.086
Feces DM, kg/d	1,732	1,609	1,533	1,506	0.032	0.001	0.010	0.150
Feces N, g/d	30.8	30.4	27.7	29.0	0.78	0.011	0.575	0.254
Urine N, g/d	13.7	26.7	14.0	25.2	1.16	0.635	0.001	0.484
Urine urea N, g/d	7.3	13.8	4.3	11.7	1.08	0.034	0.001	0.664
Urea, % of urine N	55.1	51.9	31.5	47.3	5.75	0.030	0.297	0.126
DM digestibility, %	59.5	62.4	63.0	64.2	0.68	0.001	0.010	0.239
N digested, g/d	33.2	50.2	34.5	43.3	1.75	0.135	0.001	0.033
N digestibility, %	51.8	62.4	55.2	59.1	1.52	0.957	0.001	0.044
N retained, g/d	19.5	23.5	20.5	18.1	1.53	0.198	0.630	0.065
N retained, % of N digested	57.6	45.6	57.0	41.4	2.18	0.416	0.001	0.532
SUN, m*M*	4.1	6.9	3.7	5.4	0.2	0.001	0.001	0.015

Table 4. Urea transfers in steers fed gamagrass or switchgrass hay with low or high N content

	Gamagrass		Switchgrass			*P*-value		
Urea transfers, g N/d[a]	Low	High	Low	High	SE	Grass (G)	N level	G × N
UER[b]	35.4	45.7	32.6	43.0	1.63	0.112	0.001	0.970
GER[c]	28.1	32.0	28.3	31.3	1.47	0.864	0.034	0.780
ROC[d]	8.42	9.27	7.38	9.48	0.59	0.494	0.025	0.304
% Contributions								
GER/UER	79.5	70.4	86.6	72.8	2.21	0.047	0.001	0.299
ROC/GER	30.1	29.3	26.1	30.8	1.88	0.517	0.319	0.174
ROC/UER	23.9	20.2	22.6	21.9	1.19	0.846	0.089	0.223

[a]As measured during a continuous, intravascular infusion of bis ^{15}N-urea.
[b]Urea-N entry rate.
[c]The rate at which urea enters the gastrointestinal tract.
[d]The rate at which NH_3 N from hydrolysis of urea is returned to the ornithine cycle.

Effects of Forage and N Level on Urea Metabolism and Recycling

The overall nutrient supply from our diets was not sufficient for the steers to use all of the increment in N supply for tissue growth; this conclusion is supported by decreased N retention as a percentage of N digested (Table 3), increased UER, decreased GER as a percentage of UER, and decreased ROC as a percentage of UER (Table 4). Therefore, only a limited fraction of this extra urea N was returned to the gut and partially recycled as N in microbial products. The ROC as percentage of GER (Table 4) was less than those of yearling goats fed various intakes of a grass pellet diet (36.9 to 40.7%, Sarraseca et al., 1998). Our data indicate that between 65 and 70% of the urea N entering the GIT could be incorporated into microbial constituents for later use by the steers; some of the N could be excreted in feces (Sarraseca et al., 1998; Lobley et al., 2000). However, these potential values are much higher than those obtained by Bunting et al. (1987), who reported that 55 to 58% of the SUN that entered the rumen was incorporated into microbial N in lambs fed a corn-based diet. Of course, dietary factors, such as availability of readily fermentable carbohydrate in the rumen, can focus recycling of urea into the rumen vs the lower GIT (Kennedy, 1980; Huntington, 1989) and may play a role in directing more urea N that enters the GIT to return to the circulation (Lobley et al., 2000).

In an effort to clarify the trend for increased urea production for gamagrass vs switchgrass (Table 4), N intake was included as a covariate in a subsequent ANOVA; that analysis indicated that there were no significant forage effects on any of the variables in Table 4. We conclude that differences seen between gamagrass and switchgrass in urea N production were due to differences in N concentration and subsequent N intake by the steers. Therefore, the chemical compositions of gamagrass and switchgrass at similar stages of maturity are not sufficiently distinct to provide detectable differences in urea kinetics and production traits.

Implications

Increasing N fertilization of gamagrass and switchgrass swards will increase the N concentration of harvested hays, and it will increase DM and N digestibility by steers fed those hays. However, neither efficiency of N use nor recycling of urea to the digestive tract was improved with increased N intake. Therefore, although increasing the amount of N presented to beef steers will increase the available amount of N available to them, this does not equate with an increased use of this N. Hence, once the N intake exceeds the maintenance requirements of the steer, a greater proportion is excreted as urea in the urine and not captured as the salable product, beef.

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